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Novel Optoelectronic Devices based on combining GaAs and InP on Si

Interim report 6

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1. Introduction

In the last 6 months the work has concentrated on the following topics : application of non-planar growth (SMG) for laser-waveguide coupling and multi-wavelength laser arrays using GaAs and InP based materials and use of Bonding by Atomic Rearrangement for InP on GaAs and InP on Si devices

2. Shadow masked growth devices

We have concentrated on the application of the shadow masked growth technique to the fabrication of optoelectronic devices. We have shown the fabrication of GaAs/AlGaAs and InP/InGaAsP (strained) QW multi-wavelength laser arrays and the use of SMG for the integration of a passive and active waveguiding section in GaAs based materials.

Figure 2.1 shows the layer structure of an InGaAs/InGaAsP strained MQW laser grown on a shadow masked substrate with different window widths. On the n-doped substrate (with the shadow mask) we have deposited a 500 nm n-doped lower InP cladding layer and an undoped active region consisting of 4 InGaAs strained quantum wells with InGaAsP barriers and separate confinement layers. The quantum wells were 0.8% compressively strained (composition $In_{0.64}Ga_{.36}As$) and the barriers and separate confinement layers were 15 nm, respectively 50 nm thick lattice-matched $In_{.64}Ga_{.36}As_{.77}P_{.23}$ (wavelength 1440 nm). The upper cladding layer consisted of 50 nm undoped InP that acts as diffusion barrier for the p-dopant and 1 µm p-doped InP. A 100 nm heavily p-doped $In_{.53}Ga_{.47}As$ layerwas used as top contact layer. The growth parameters were determined for the growth on planar substrates. The choice of 1440 nm material for the barriers and confinement layers is not ideal, but was imposed by restrictions in our MOCVD system. After growth, one additional lithography and wet etch step is used for the removal of the shadow mask. Due the variation in window width (10, 15, 20 µm mask and no mask), one obtains a different emission wavelength for the lasers because the QW thickness variation results in a variation in the bandgap. A cross-section of the laser diode after processing is shown in figure 2.2. A classical ridge laser is processed with a SiN isolation layer and using Zn-Au and Au-Ge-Ni as contact metallisations.

The threshold current of all the lasers was between 65 and 75 mA. This relative high value is caused by the stripe width of the lasers and the fact that the laserstructure has not been optimized yet. The stripes were 11 µm broad, what is to much for single mode operation. Figure 2.3 shows the spectral outputs of the different lasers form one array. We observe a wavelength span of 130 nm around 1.55 µm which is well suited for Wavelength Division Multiplexing (WDM) experiments.

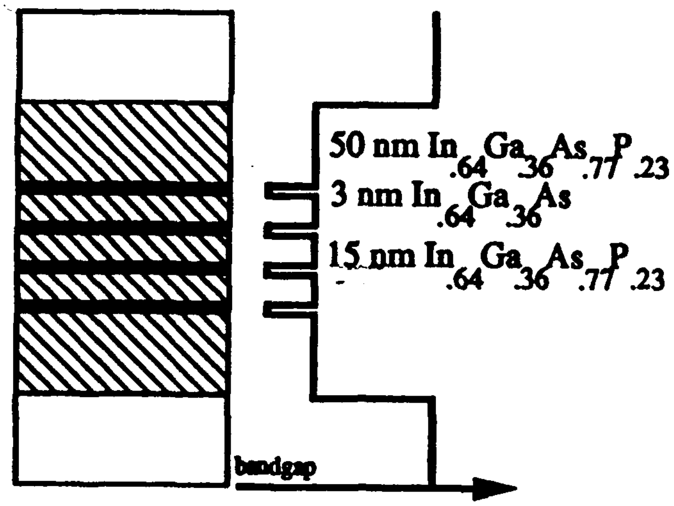

Figure 2.1. Layer structure of the InGaAs/InGaAsP strained MQW lasers.

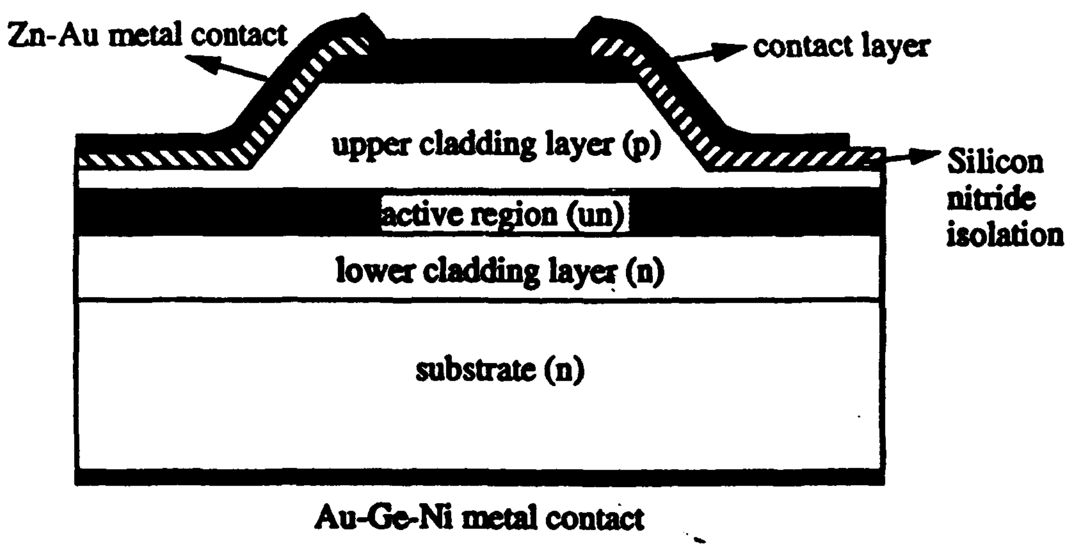

Figure 2.2. Cross-section of a laser after processing.

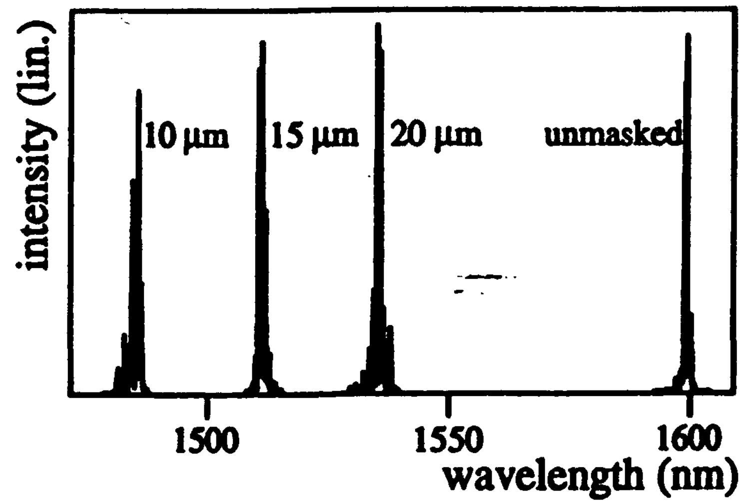

Figure 2.3. Emission spectrum of the InGaAs/InGaAsP laser array.

In a similar way we have shown that the technology is usefull for GaAs based multiwavelength laser arrays. An emission spectrum of different lasers from the same array is shown in figure 3.4

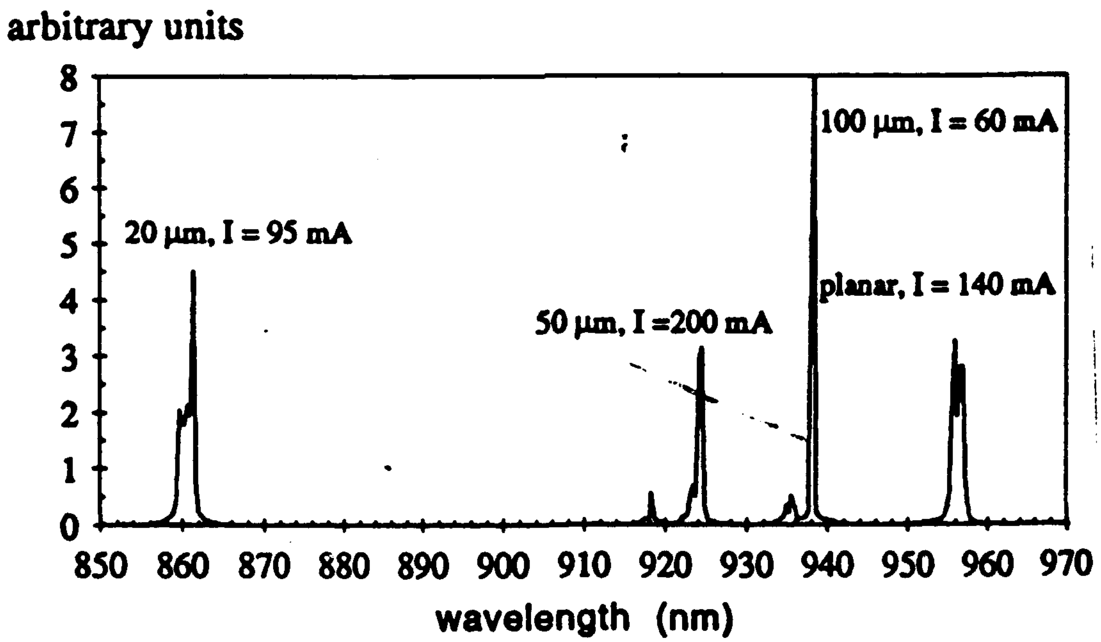

Figure 2.4. Emission spectrum of a InGaAs/AlGaAs strained QW multiwavelength laser array

Finally we have applied the SMG technique to the fabrication of an extended cavity laser using InGaAs/AlGaAs strained QWs. A principle of the mask layout and corresponding layer structure is shown in figure 2.5. The laser structure is grown on the unmasked region and the passive section is grown in the masked part of the substrate. The mask width is varied between 20 and 100 μm. The waveguide section is transparant due to the reduction in growth velocity on the SMG part. This reduced growth velocity results in thinner QWs and therefore a larger bandgap energy. This will be transparant for the light emitted from the active region. The active region was 1 mm long and the passive section has been varied from 3.5 to 2 mm. A shift in bandgap of 36 meV between the active and passive part is measured for a 100 μm channel and this increases to 49 meV for the 50 μm channels. The emission wavelength of a laser with a 1 mm long cavity without a passive section is 930 nm and the threshold current is 55 mA. If we add a passive waveguide the emission wavelength shifts due to the change in gain spectrum caused by the wavelength dependend losses in the cavity. This wavelength shift depends on the bandgap difference between the passive and active sections and hence depends on the channel width. Figure 2.6 shows the spectra of extended cavity lasers with a 1 mm long active and 2 mm long passive part for different widths W. We have also realised a laser with a cavity length of 4.5 mm consisting of a 1 mm and 3.5 mm passive part. Lasing action occured, centered around 933 nm with a threshold current of 90 mA, showing a relative small increase compared to the 55 mA threshold current of lasers without the passive section.

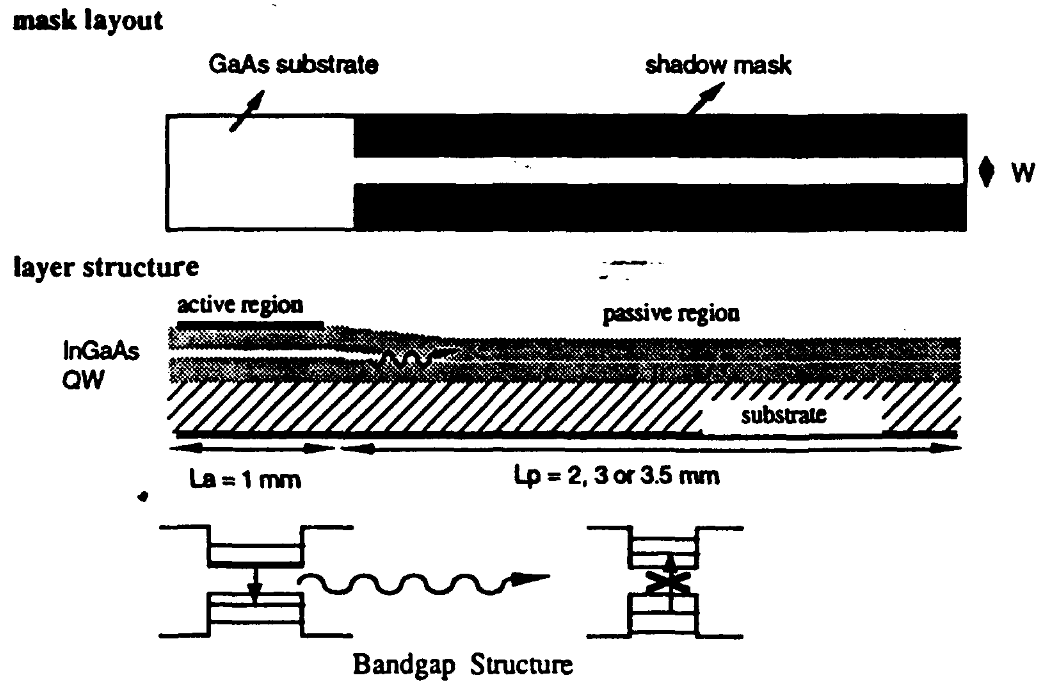

Figure 2.5. Topview of the mask layout and cross-section of the layer structure of an extended cavity laser.

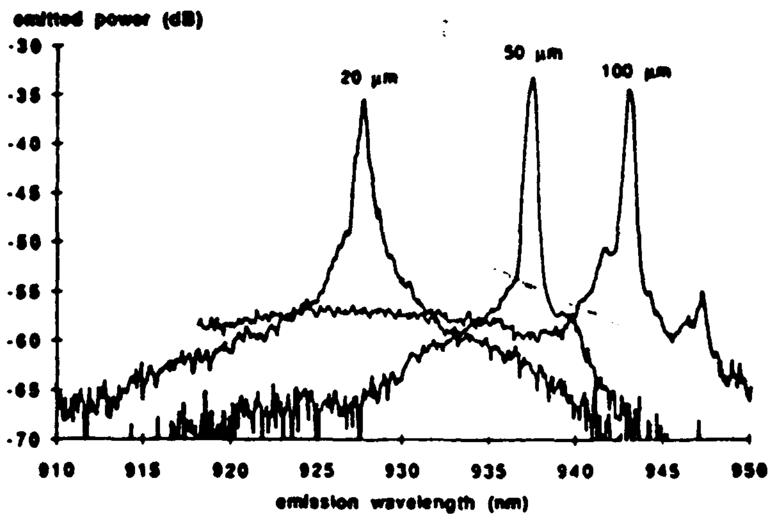

Figure 2.6. Emission spectra of extended cavity lasers in different channels.

3. InP on InP and GaAs using Bonding by Atomic Rearrangement

Bonding by Atomic Rearrangement (BAR) is a relatively new technology introduced by Bellcore. It is very similar to the Si-waferbonding technique and it allows to combine materials with a different lattice constant (e.g.: InP on GaAs or InP on Si). The technique is based on the heating (typically 600 °C for 30 min) of the two different substrates under a hydrogen atmosphere. Initial experiments have been done showing a very good mechanical bonding of InP on InP and InP on GaAs wafers. A MQW PIN InP/InGaAs modulator structure has been characterized by photocurrent and photoluminescence measurements before and after BAR to a GaAs and InP substrate. A strong reduction in material quality was observed together with a shift in the bandgap energy of the MQW. These initital experiments need further investigation.

6. Conclusion

In this sixt report we have descibed some of our most recent results on the fabrication of novel optoelectronic devices. The work has progressed well and some new results have been obtained : SMG growth of InGaAs/AlGaAs strained QW extended cavity, SMG growth of InGaAs/AlGaAs and InGaAs/InGaAsP strained (M)QW multiwavelength laser arrays, bonding by atomic rearangement (BAR) of InP/InGaAs MQW modultators on InP and GaAs substrates.

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